REMARKS

Claims 1, 2, 4, 6, 8, 11-12, 16, 20 21, 22, 24, 30, 32, 34, and 65-73 are all claims presently pending in the application. Applicant has canceled claims 9 and 10 without prejudice or disclaimer. Applicant has added new claims 65-73 to more particularly define the invention. Independent Claims 1 and 12 have been amended to include dependent claims 10 and 20. Claims 9 and 21 stand rejected under 35 U.S.C. § 112, Second Paragraph. Claims 1, 2, 4, 6, 8, 9, 11-12, 16, 21, 22, 24, 30, 32 and 34, stand rejected under prior art grounds.

Claims 1, 2, 4, 6, 8, 12 and 16, stand rejected under 35 U.S.C. § 102(b) as being anticipated by, or in the alternative under 35 U.S.C. § 103(a) as obvious over Akutsu, et al. (U.S. Pat. No. 4,749,548). Claims 11, 20-22, 24, 30, 32 and 34 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Akutsu, et al. taken with Dubin (U.S. Pat. No. 6,249,055 B1) or Edelstein, et al. (U.S. Pat. No. 6,181,012 B1).

These rejections are respectfully traversed in view of the following discussion.

It is noted that the amendments are made only to more particularly define the invention and not for distinguishing the invention over the prior art, for narrowing the scope of the claims, or for any reason related to a statutory requirement for patentability.

It is further noted that, notwithstanding any claim amendments made herein, Applicant's intent is to encompass equivalents of all claim elements, even if amended herein or later during prosecution.

I. THE CLAIMED INVENTION

Applicant's invention, as disclosed and claimed, for example by independent claim 1, and similarly independent claim 12, is directed to an electrically conductive layer including a copper alloy interconnection layer which fills a trench groove and includes a copper alloy comprising at least one of Ag, As, Bi, and Sb at not less than 0.1 percent by weight, so as to increase a crystal grain size and reduce crystal grain boundaries. The copper alloy further includes at least one of Mo, Ta and W in a range of not less than 0.1 percent by weight to not more than 1 percent by weight. At least one of Mo, Ta and W being higher in density than copper is present on said crystal grain boundaries, whereby at least one of Mo, Ta and W suppresses a diffusion of copper. (See Page 39, lines 1-7; Page 59, line 10-Page 60, line 10; and Figures 5A-6B).

The other embodiments, as defined by independent claims 22 and 30, recite somewhat similar limitations, in particular, the semiconductor device, includes, in pertinent part, "an interconnection layer formed on the barrier metal layer, and comprising a copper alloy which fills the trench groove and includes at least one of Ag, As, Bi, and Sb in a range of not less than 0.1 percent by weight to not more than a maximum solubility limit of copper, ..." (See above).

As mentioned above, an important aspect of the invention is a copper alloy interconnection layer which fills a trench groove and includes a copper alloy comprising at least one of Ag, As, Bi, and Sb at not less than 0.1 percent by weight, so as to increase a crystal grain size and reduce crystal grain boundaries. A similarly important aspect is an interconnection layer formed on the barrier metal layer, and comprising a copper alloy which fills the trench groove and includes at least one of Ag, As, Bi, and Sb in a range of not less than 0.1 percent by weight to not more than a

maximum solubility limit of copper. Based on these aspects, "it is easy to accurately control the width of the groove in the insulation layer. This means it [is] easy to accurately control the width of the copper-alloy interconnection. This allows realization of the fine interconnection with the reduced width in order to realize the increased degree of integration of the semiconductor device." (Page 21, lines 17-22; Page 29, lines 9-15; Page 33, lines 2-7; Page 39, lines 1-7; Page 40, line 22-Page 41, line 3; and Page 59, line 10-Page 60, line 10).

As a result of this invention, the resultant structure suppresses the mass-transfer of copper through the copper alloy and prevent the resistivity of the copper alloy from becoming too high. Thus, a reduction in electromigration of an interconnection layer in a semiconductor device is produced decreasing the probability of disconnection and cracking of the interconnection layer, thereby improving the reliability and productivity of the semiconductor device. (See Page 6, line 10 - Page 7, line 16; Page 13, lines 17-24; Page 26, lines 8-20; and Page 44, lines 1-9).

II. 35 U.S.C. § 112, Second Paragraph Rejection

Applicant, as indicated above, has amended claims 20 and 21 in a manner believed fully responsive to all points raised by the Examiner with regard to the 35 U.S.C. § 112, Second Paragraph Rejection.

In view of the foregoing, the Examiner is respectfully requested to withdraw this rejection.

III. THE PRIOR ART REJECTION

A. The Akutsu Reference

Regarding claims 1, 2, 4, 6, 8, 12 and 16, Akutsu, et al. ("Akutsu") fails to teach or suggest the features of independent claim 1, including a copper alloy interconnection layer which fills a trench groove and includes a copper alloy, which includes at least one of Ag, As, Bi, and Sb at not less than 0.1 percent by weight, so as to increase a crystal grain size and reduce crystal grain boundaries. Similarly, Akutsu fails to teach or suggest the features of independent claim 12, including a copper alloy interconnection layer which fills a trench groove and includes at least one of Mo, Ta and W in a range of not less than 0.1 percent by weight to not more than 1 percent by weight, the copper alloy interconnection layer comprises a copper alloy. (See Page 39, lines 1-7; Page 59, line 10-Page 60, line 10; and Figures 5A-6B).

Applicant agrees with the Examiner that Akutsu does not teach or suggest the above feature, and in particularly, "does not recite the conventional structure supporting such interconnect to semiconductor devices, e.g., the provision of insulation and interconnect in an opening with or without barrier therein." (See Office Action, Page 6, Last Paragraph).

The present invention is characterized in that an electrical conductive layer includes 0.1 percent by weight or more of at least one among Ag, As, Bi and Sb, and includes at least one among Mo, Ta, and W in the range between 0.1 percent by weight and 1 percent by weight, inclusive.

In contrast, Akutsu discloses a lead wire made of a copper alloy containing 1) 0.05 to1 wt. % of Cr, 2) 0.05 to 0.3 wt % of Zr, 3) 0 to 2 % of at least one among a metal in a first group selected from Ni, Sn, Fe, Co, and Be, 4) 0-1 % of a metal in a second group selected from Mg, Si, Al, Zn, Mn, B, P, Li, Y and a rare earth element, 5) 0-2 % of a metal in a third group selected from

Ti, Nb, V, Ta, Hf, Mo and W.

In other words, Akutsu discloses that a "copper alloy contains at least one [element] among Mo, Ta, and W in the range between 0.1 wt.% and 1 wt. % inclusive," however, Akutsu does not disclose that a "copper alloy contains 0.1 wt. % or more of at least one among Ag, As, Bi and Sb." Therefore, the present invention has a difference in its structure from Akutsu, even if Akutsu is taken into account. Accordingly, the present invention has novelty.

Indeed, Akutsu only pertains to a copper alloy lead material for use in a semiconductor device. Accordingly, Akutsu, as indicated above, only discloses a copper alloy lead material without any of the structure supporting the interconnect to the semiconductor device. Thus, Akutsu does not teach or suggest any interconnection layer, let alone, an electrically conductive layer, which includes a copper alloy interconnection layer which fills a trench groove and includes at least one of Ag, As, Bi, and Sb at not less than 0.1 percent by weight, so as to increase a crystal grain size and reduce crystal grain boundaries as claimed by Applicant. (See Akutsu at Abstract; and Column 1, lines 5-10 and lines 45-60).

In contrast, as noted above, in Applicant's invention (e.g., as defined in Claims 1 and 12), the electrically conductive layer includes a copper alloy interconnection layer which fills a trench groove and includes at least one of Ag, As, Bi, and Sb at not less than 0.1 percent by weight, so as to increase a crystal grain size and reduce crystal grain boundaries. Accordingly, "it is easy to accurately control the width of the groove in the insulation layer. This means it [is] easy to accurately control the width of the copper-alloy interconnection. This allows realization of the fine interconnection with the reduced width in order to realize the increased degree of integration of the

semiconductor device." (Page 21, lines 17-22; Page 29, lines 9-15; Page 33, lines 2-7; Page 39, lines 1-7; Page 40, line 22-Page 41, line 3; and Page 59, line 10-Page 60, line 10).

Consequently, as indicated above, the Akutsu copper alloy material without any structure to support an interconnect, is specifically directed to providing a material with allegedly high degrees of strength and elongation. However, as discussed, the Akutsu copper alloy without the interconnection supporting structure does not provide a resultant structure, like Applicant's invention, which suppresses the mass-transfer of copper through the copper alloy and prevent the resistivity of the copper alloy from becoming too high. Thus, Applicant's invention, not Akutsu, provides for a reduction in electromigration of an interconnection layer in a semiconductor device and decreases the probability of disconnection and cracking of the interconnection layer, thereby improving the reliability and productivity of the semiconductor device. (See Page 6, line 10 - Page 7, line 16; Page 13, lines 17-24; Page 26, lines 8-20; and Page 44, lines 1-9).

Thus, Akutsu does not disclose, teach or suggest, including that a copper alloy interconnection layer which fills a trench groove and includes a copper alloy, which includes at least one of Ag, As, Bi, and Sb at not less than 0.1 percent by weight, so as to increase a crystal grain size and reduce crystal grain boundaries as recited in independent claim 1 nor that a copper alloy interconnection layer which fills a trench groove and includes at least one of Mo, Ta and W in a range of not less than 0.1 percent by weight to not more than 1 percent by weight, the copper alloy interconnection layer comprises a copper alloy as recited in independent claim 12, and related dependent claims 2, 4, 6, 8, and 16.

B. The § 103(a) Rejection of Akutsu, in view of Dubin or Edelstein

Regarding independent claims 1, 12, 22 and 30, and related dependent claims 11, 20-22, 24, 32 and 34, first, the references, separately, or in combination, fail to teach, disclose or provide a reason or motivation for being combined.

Neither Dubin ("Dubin") nor Edelstein, et al. ("Edelstein") have the same aim as Akutsu.

In particular, Edelstein, et al. ("Edelstein") provides a copper alloy interconnection structure with an improved resistivity to electromigration and improved adhesiveness property. (See Edelstein at Abstract; Column 1, lines 5-15; and Column 6, lines 10-23). Dubin ("Dubin") provides a copper or copper-alloy interconnection structure free of any copper diffusion and having a highly anti-corrosion property. (See Dubin at Abstract; Column 1, lines 5-10; and Column 3, lines 55-62).

Nothing within Dubin, which relates to a copper or copper-alloy interconnection structure free of any copper diffusion and having highly anti-corrosion properties, has anything to do with a copper alloy lead material without an interconnection structure for use in a semiconductor device, which displays high degrees of strength and elongation as disclosed above in Akutsu.

Similarly, nothing within Edelstein, which relates to a copper alloy interconnection structure with an improved resistivity to electromigration and improved adhesiveness property, has anything to do with a copper alloy lead material without an interconnection structure for use in a semiconductor device, which displays high degrees of strength and elongation as disclosed above in Akutsu. Thus, Akutsu teaches away from being combined with another invention, such as, Dubin or Edelstein.

Therefore, one of ordinary skill in the art would not have combined these references, absent hindsight.

Please note, "the mere fact that references can be combined or modified does not render the resultant combination obvious unless the references also suggest the desirability of the combination." In this situation, the above references do not suggest any benefit or desirability of being combined. (See MPEP Section 2143.01).

Secondly, the present invention is characterized in that an interconnection layer includes at least one among Ag, As, Bi and Sb, in a range of 0.1 wt. % or more to less than a solid-soluble limit of copper, and further includes at least one among Mo, Ta, and W in the range between 0.1 percent by weight and 1 percent by weight, inclusive.

In contrast, as indicated above, Akutsu discloses a lead wire made of a copper alloy containing 1) 0.05 to1 wt. % of Cr, 2) 0.05 to 0.3 wt % of Zr, 3) 0 to 2 % of at least one among a metal in a first group selected from Ni, Sn, Fe, Co, and Be, 4) 0-1 % of a metal in a second group selected from Mg, Si, Al, Zn, Mn, B, P, Li, Y and a rare earth element, 5) 0-2 % of a metal in a third group selected from Ti, Nb, V, Ta, Hf, Mo and W.

In other words, Akutsu discloses that a "copper alloy contains at least one among Mo, Ta, and W in the range between 0.1 wt.% and 1 wt. % inclusive," however, Akutsu does not disclose that a "copper alloy contains 0.1 wt. % or more of at least one among Ag, As, Bi and Sb."

Edelstein, as previously discussed, also discloses the following: 1) a copper alloy seed layer, which includes at least one element among Sn, In, Zr, Ti, C, O, N, Cl and S, 2) a copper alloy seed layer includes at least one element among Al, Mg, Be, Ca, Sr, Ba, Sc, Y, La, Ce, Pr, Nd,

Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, V, Nb, Ta, Cr, Mo, W, Mn, Re, Si and Ge, 3) a copper alloy seed layer, which includes at least one element among B, O, N, P, Fe, Ru, Os, Co, Rh and Ir, 4) a metal seed layer is selected from Ag, Mo, W or Co, 5) an electrical conductive layer of copper contains 0.01 to 10 wt. % of an alloy element selected from C, N, O, Cl and S, and 6) a copper alloy seed layer includes 0.25 to 1.5 atom. % of Sn or In.

However, Edelstein does not disclose or suggest that "an interconnection layer includes at least one among Ag, As, Bi and Sb in the range of 0.1 wt. % or more to less than a solid-soluble limit into copper, and further includes at least one among Mo, Ta and W in the range between 0.1 wt. % and 1 wt %, inclusive."

Further, Dubin discloses that a seed layer made of Mg, Al, Zn, Zr, Sn, Ni, Pd, Ag or Au, and alloyed copper.

However, Dubin does not disclose or suggest that "an interconnection layer includes at least one among Ag, As, Bi and Sb in the range of 0.1 wt. % or more to less than a solid-soluble limit into copper, and further includes at least one among Mo, Ta and W in the range between 0.1 wt. % and 1 wt %, inclusive."

Therefore, even if Akutsu, Dubin and Edelstein are combined, they are different from the characteristics of the above amended claims 11, 20-22, 30, 32, and 34 in the present invention, that is, "an interconnection layer including at least one among Ag, As, Bi and Sb in the range of 0.1 wt. % or more to less than a solid-soluble limit into copper, and further including at least one among Mo, Ta and W in the range between 0.1 wt. % and 1 wt. % inclusive."

Consequently, the present invention is novel and not obvious even if Akutsu, Dubin and

Edelstein are taken into account.

Thus, in short, even assuming that the references would have been combined, Dubin does not teach or suggest the features of independent claim 1, and similarly independent claim 12, including that a copper alloy interconnection layer which fills a trench groove and includes a copper alloy, which includes at least one of Ag, As, Bi, and Sb at not less than 0.1 percent by weight, so as to increase a crystal grain size and reduce crystal grain boundaries. Similarly, Dubin also does not teach or suggest the features of independent claims 22 and 30, including that an interconnection layer formed on the barrier metal layer, and comprising a copper alloy which fills the trench groove and includes at least one of Ag, As, Bi, and Sb in a range of not less than 0.1 percent by weight to not more than a maximum solubility limit of copper. (See Page 39, lines 1-7; Page 59, line 10-Page 60, line 10; and Figures 5A-6B).

In contrast, Figures 1-7 of Dubin only disclose a copper or copper alloy interconnection structure free of any copper diffusion and having a high resistivity to corrosion. Applicant respectfully submits that the Office Action mischaracterizes Dubin as Dubin only teaches a copper alloy seed layer 56, which does not fill a trench 12. In particular, a dual damascene copper-interconnection structure includes the trench 12, which includes a barrier layer 52, an aluminum-alloy or magnesium alloy layer 53 over layer 52, a seed layer 56 over the aluminum-alloy or magnesium alloy layer 53, and copper via the copper metallization 54 is deposited over the seed layer 56, thus filing the damascene opening and extending above the upper surface of the substrate 50 as indicated in Figures 6 and 7. Contrary to the assertion in the Office Action, "the seed layer 56 is deposited on the Al alloy or Mg alloy layer 53 for enhanced nucleation and adhesion of the electroplated or electroless plated Cu or Cu alloy layer [54]." Thus, the seed layer 53 is more

structurally and functionally equivalent to an adhesive, single layer, which does not fill the trench 12. (See Office Action, Page 7, Second Paragraph; Column 5, line 45-Column 6, line 67; Column 7, lines 7-21 and lines 39-47; and Figures 1-5).

For example in Figures 6 and 7, even without the seed layer 56, the aluminum-alloy or magnesium alloy layer 53 "diffuse through the Cu metallization 61, accumulate on the exposed surface, and react with oxygen to form a self-passivating Al oxide or Mg oxide layer 70 encapsulating a [copper] interconnection [line] 61." Thus, the copper interconnection 61 fills the trench not a copper alloy filling the trench. (See Column 7, lines 22-33; and Figures 6 and 7).

In contrast, as discussed above, Applicant teaches that the electrically conductive layer, or similarly the semiconductor device, includes a trench-groove formed in an inter-layer insulator 10 where a barrier metal layer 2 is formed on the top surface of the inter-layer insulator 10 and a seed layer 11, which is comprised of a copper alloy, is formed on the barrier metal layer 2. Further, "with reference to Figure 5D, a copper layer 12 is further formed on the seed layer 11" where a heat treatment causes " a thermal diffusion of at least one of As, Bi, and Sb in the seed layer 11 to the copper layer 12, whereby a copper alloy interconnection layer 1 is formed on the barrier metal layer 2 and within the trench groove of the inter-layer insulation 10. Thus, the copper alloy interconnection layer fills the trench groove. (See Page 57, line 3- Page 58, lines 15; and Figures 3 and 5A-5E).

Similarly, a copper-alloy interconnection layer 200 exists on a barrier metal layer 2, which extends on a bottom and side walls of the trench groove, so that "the copper-alloy interconnection 200 fills the trench groove of the inter-layer insulation 10." (See Page 58, line 15-Page 60, line 9; and Figures 6A-6D).

Accordingly, Dubin does not disclose, teach or suggest that the electrically conductive layer includes a copper alloy interconnection layer which fills a trench groove and includes a copper alloy, which includes at least one of Ag, As, Bi, and Sb at not less than 0.1 percent by weight, so as to increase a crystal grain size and reduce crystal grain boundaries. Similarly, Dubin also does not disclose, teach or suggest that an interconnection layer formed on the barrier metal layer, and comprising a copper alloy which fills the trench groove and includes at least one of Ag, As, Bi, and Sb in a range of not less than 0.1 percent by weight to not more than a maximum solubility limit of copper as claimed by Applicant.

Thus, Dubin only teaches, at best, a copper seed layer, which is a single layer, without filling the trench 12, and therefore, does not teach Applicant's claimed invention.

Edelstein also does not resolve the deficiencies of Akutsu.

Rather Figures 1-4 of Edelstein, as discussed in previous amendments, only disclose a copper-alloy interconnection structure with improved resistivity to electromigration and an improved adhesion property. Applicant respectfully submits that the Office Action mischaracterizes Edelstein as Edelstein only teaches a seed layer 76, 78, 86, which does not fill a trench in the insulators 54, 100. The copper-alloy interconnection structure includes the seed layer 76, 78, 86 inserted between the main copper conductor layer 46, 56, 60, 82 and a barrier or liner layer 72 included in a dual-damascene structure. Although the seed layer 76, 78, 86, may comprise a copper-alloy including copper in combination with at least one other element, the main copper conductor layer 46, 56, 60, 82 primarily comprises copper though may include "a mixture of copper with an alloying element such as C, N, O, Cl or S."

Contrary to the assertion in the Office Action, the seed layer 76, 78, 86 is more structurally and functionally equivalent to a single, seed layer not the copper alloy as recited in Applicant's

invention. (See Office Action, Page 7, First Paragraph; Column 6, line 10-Column 7, line 50; and Figures 1-4D).

Indeed, the Edelstein seed layer 76, 78, 86 functions to "provide a base onto which [the] main [copper] conductor layer 46, 56, 60, 82 may be deposited," whereas, as indicated above, Applicant's invention includes the seed layer 11" where a heat treatment causes "a thermal diffusion of at least one of As, Bi, and Sb in the seed layer 11 to the copper layer 12, whereby a copper alloy interconnection layer 1 is formed on the barrier metal layer 2 and within the trench groove of the inter-layer insulation 10.

Accordingly, Edelstein does not teach or suggest the use of thermal diffusion of the seed layer but instead suggests that chemical vapor deposition of the main copper conductor layer for deposition of the copper on the seed layer may be desirable. Thus, Edelstein appears to teach that the seed layer does not diffuse and, as indicated, only provides "improved surface properties suitable for deposition of the main conductor copper body." Therefore, only the main copper conductor layer 46, 56, 60, 82, fills the trench not the seed layer. (See Column 7, line 20-Column 9, line 45).

Please note, as indicated above, the main copper conductor layer 46, 56, 60, 82 primarily comprises copper but may include "a mixture of copper with an alloying element such as C, N, O, Cl or S. However, the main copper conductor layer 46, 56, 60, 82, with any of the above elements still does not form Applicant's copper alloy, which includes at least one of As, Bi and Sb. Thus, the main copper conductor layer is not structurally equivalent to Applicant's copper alloy. (See Column 7, line 63-Column 8, line 4).

Accordingly, Edelstein does not disclose, teach or suggest that the electrically conductive layer includes a copper alloy interconnection layer which fills a trench groove and includes a

copper alloy, which includes at least one of Ag, As, Bi, and Sb at not less than 0.1 percent by weight, so as to increase a crystal grain size and reduce crystal grain boundaries as claimed by Applicant. Similarly, Dubin also does not disclose, teach or suggest that an interconnection layer formed on the barrier metal layer, and comprising a copper alloy which fills the trench groove and includes at least one of Ag, As, Bi, and Sb in a range of not less than 0.1 percent by weight to not more than a maximum solubility limit of copper as claimed by Applicant.

Thus, Applicant traverses the assertion in the Office Action that Dubin or Edelstein, alone or in combination, with Akutsu teach Applicant's claimed invention.

Consequently, both the Dubin and Edelstein conventional structures are unsuitable for effectively producing a copper alloy with relatively large crystal grain sizes and reduced crystal grain boundaries in a current flow direction which suppress the mass-transfer of copper through the copper alloy and prevents the resistivity of the copper alloy from becoming too high. (See (See Page 6, line 10 - Page 7, line 16; Page 13, lines 17-24; Page 26, lines 8-20; and Page 44, lines 1-9).

For at least the reasons outlined above, Applicant respectfully submits that Akutsu, Edelstein or Dubin, separately or in combination, do not teach or suggest all of the features of independent claims 1, 12, 22, and 30, and related dependent claims 11, 20, 21, 24, 32 and 34, which are patentable not only by virtue of their dependency from their independent claims but also by the additional limitations they recite.

For the reasons stated above, the claimed invention is fully patentable over the cited references.

IV. FORMAL MATTERS AND CONCLUSION

In view of the foregoing, Applicant submits that claims 1, 2, 4, 6, 8, 11-12, 16, 20-22, 24, 30, 32, 34, and 65-73, all the claims presently pending in the application are patentably distinct over the prior art of record and are in condition for allowance. The Examiner is respectfully requested to pass the above application to issue at the earliest possible time.

Should the Examiner find the application to be other than in condition for allowance, the Examiner is requested to contact the undersigned at the local telephone number listed below to discuss any other changes deemed necessary in a telephonic or personal interview.

The Commissioner is hereby authorized to charge any deficiency in fees or to credit any overpayment in fees to Attorney's Deposit Account No. 50-0481.

Respectfully Submitted,

Date: 6/10/04

Fredric J. Zimmerman, Esq.
Reg. No. 48,747

McGinn & Gibb, PLLC
8321 Old Courthouse Rd., Suite 200
Vienna, Virginia 22182
(703) 761-4100
Customer No. 21254